Moon Mineral Mapper (M^3): A high Uniformity and High Precision Science Imaging Spectrometer in the Solar Reflected Spectrum

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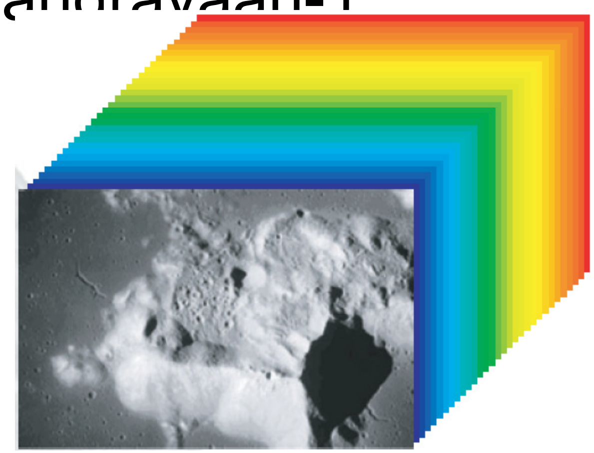
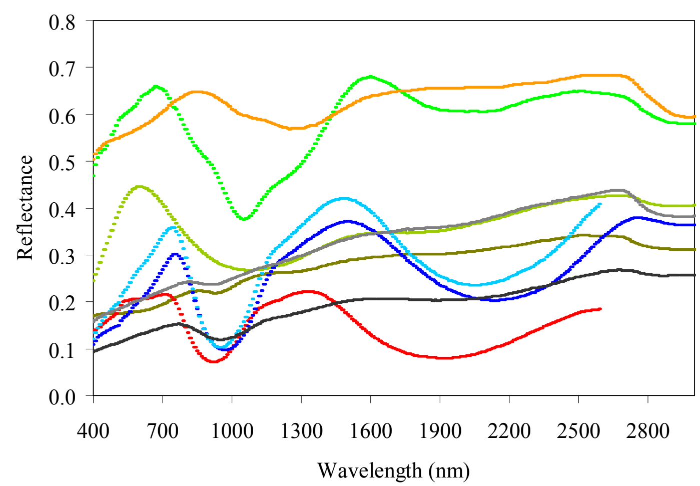
Overview

- Introduction and Science Goals
- Previous Measurements
- Moon Spectroscopy
- Measurement Approach
- Summary and Conclusion

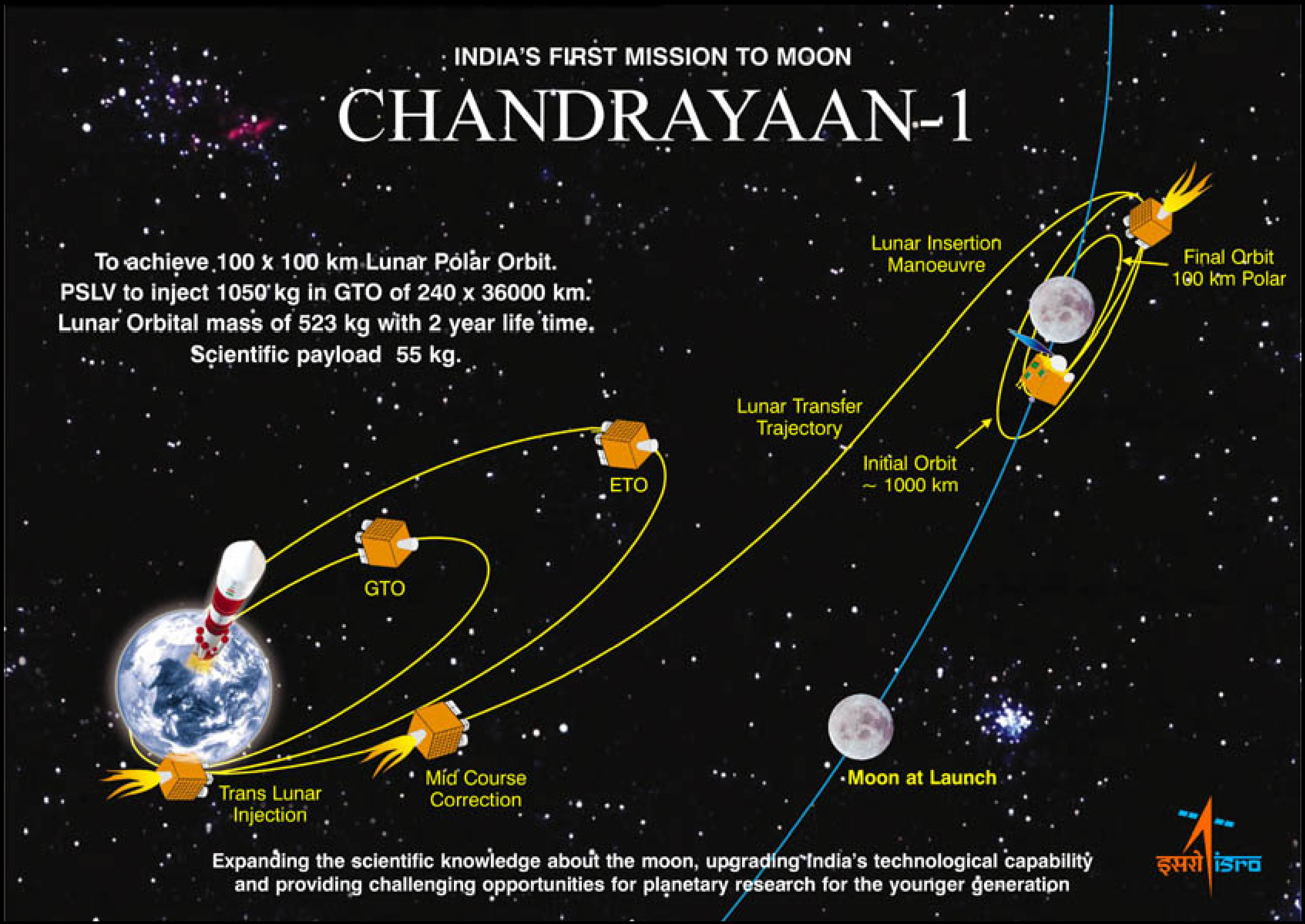
M^3 Introduction

- M3 is a NASA Discovery Mission of Opportunity Science Investigation selected in February of 2005
- The Science of M3 is based upon imaging spectroscopy measurements in the spectral range from 430 to 3000 nm
- The spectral range, resolution and expected results are tied closely to experience with AVIRIS
- M3 is planned to fly on an Indian Mission to the Moon named Chandrayaan-1





Mission Overview:M3 on Chandrayaan-1



M^3 Science Goals

- Primary Science Goal: Characterize and map the lunar surface composition in the context of its geologic evolution. This translates into several science sub-topics to be addressed.

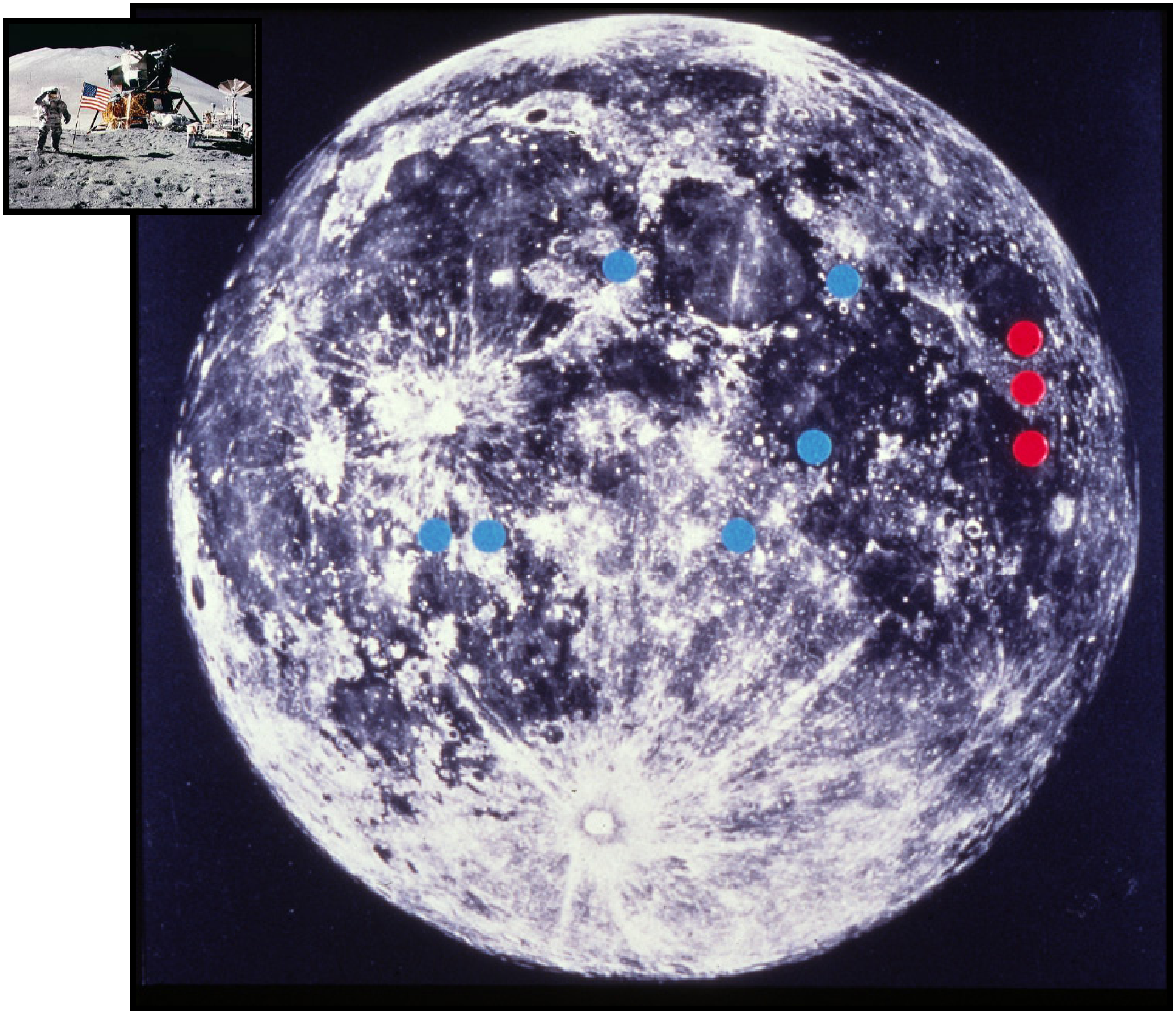
- Primary Exploration Goal: Assess and map the Moon mineral resources at high spatial resolution to support planning for future, targeted missions.

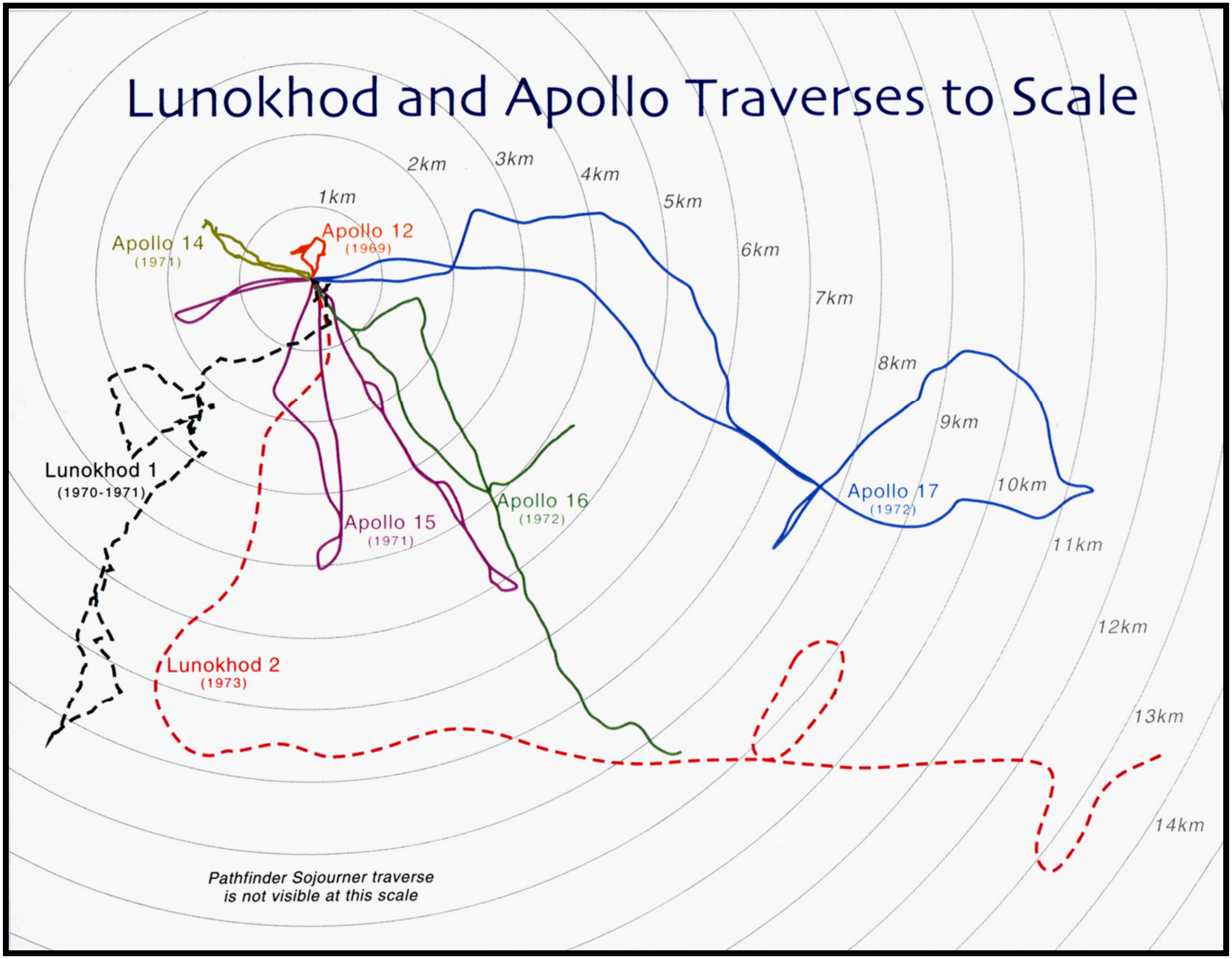
Science Goals

- Evaluate primary crustal components and their distribution across the highlands.
- Characterize the diversity and extent of different types of basaltic volcanism.
- Identify and assess deposits containing volatiles.
- Map fresh craters to assess abundance of small impacts in the recent past.
- Identify and evaluate concentrations of unusual/unexpected minerals.

M3 Goals	Science Objectives	Measurement Goals and Requirements
Geologic Evolution		
Crust	Characterize lunar highland rocks in context of geologic processes	Resolve diagnostic mineral absorption bands of primary highland rocks. Reflectance* of surface 0.7-2.6 µm at <100 m spatial and <30 nm spectral resolution
Basalts	Identify and characterize the diversity of lunar volcanism.	Resolve diagnostic mineral absorption bands of basalts and estimate TiO_2 of mare soils. Reflectance* of surface 0.4-2.6 µm at <100 m spatial and <30 nm spectral resolution
Volatiles	Identify and map the presence of hydrous phases	Detect trace amounts (of H_2O and OH from diagnostic features near 3 µm. Reflectance* of surface 2.6-3.0 µm @ 50 nm resolution
Fresh Craters	Determine the recent impact flux at 1 AU	Determine the number and size of recent ~50m impactors by identifying recent craters <0.5 km. Reflectance of surface 400 - 2500 nm; global coverage at ~100 m.
Unknown	Identify areas of rare or unseen lunar materials	Resolve diagnostic mineral absorption bands and compare with known species. Reflectance* of surface 0.4-2.6 µm at <100 m spatial and 10 nm spectral resolution
Resources		
Polar	Determine if polar H is H_2O	Detect trace amounts (of H_2O and OH from diagnostic features near 3 µm. Reflectance* of surface 2.6-3.0 µm @ 50 nm resolution
Local	Identify and map areas with diverse "feedstock" available	Map the composition across potential landing sites. Reflectance* of surface 0.4-2.6 µm at <100 m spatial and 10 nm spectral resolution

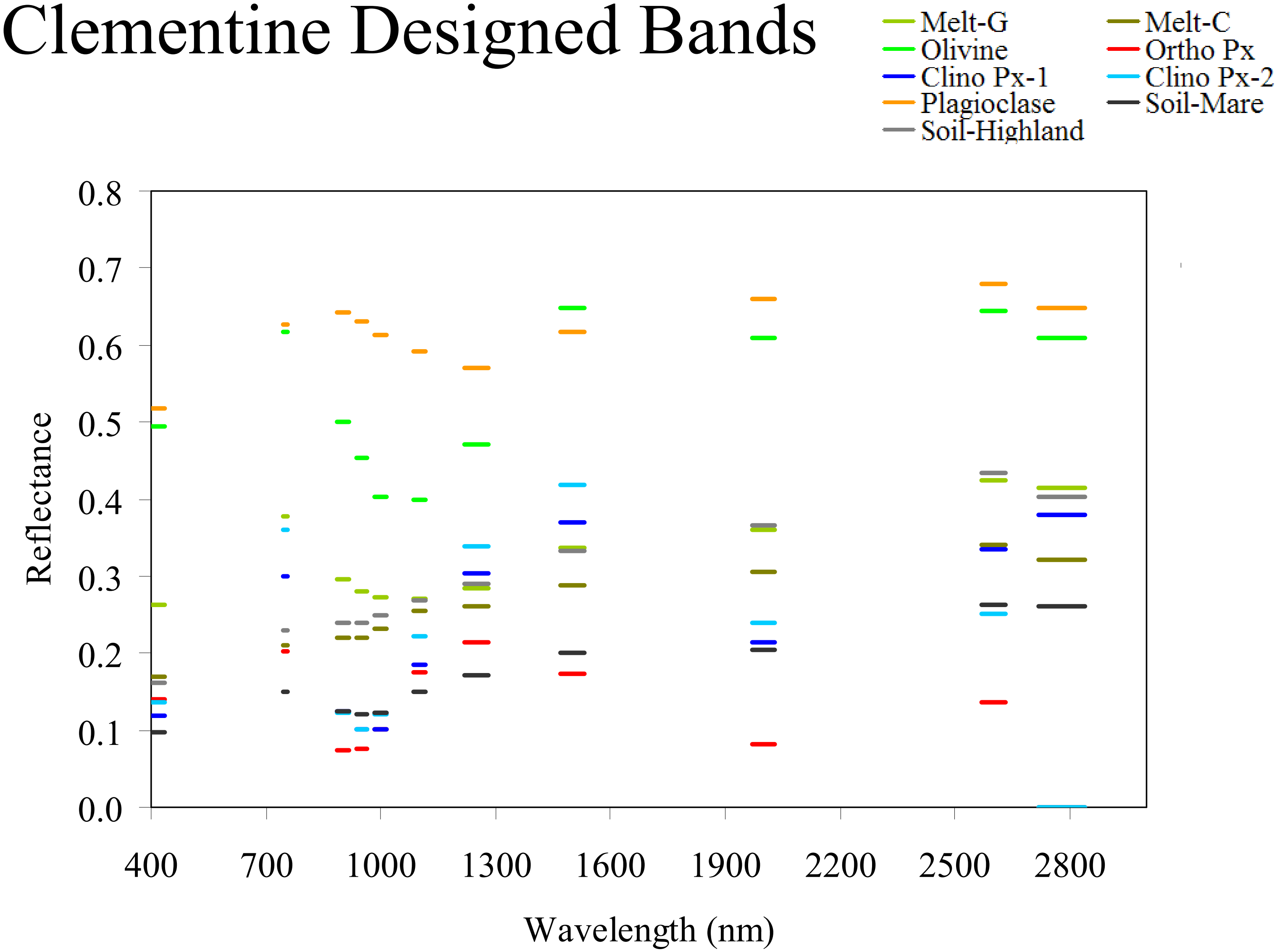
Previous Measurements and Current Understanding





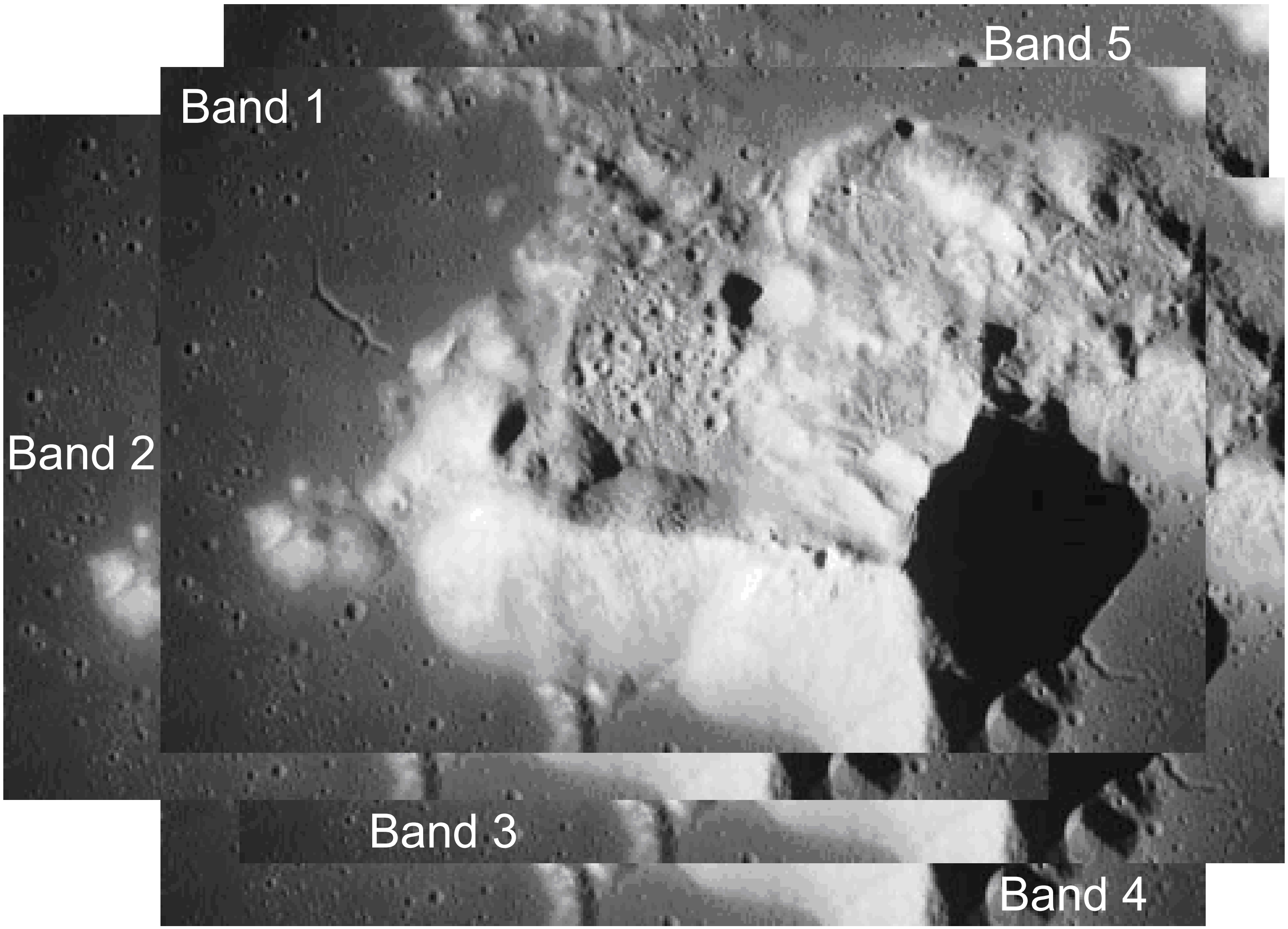
Lunokhod and Apollo Traverses to Scale
1km
2km
3km
4km
5km
6km
7km
8km
9km
10km
11km
12km
13km
14km
Apollo 12
(1969)
Apollo 14
(1971)
Apollo 15
(1971)
Apollo 16
(1972)
Apollo 17
(1972)
Lunokhod 1
(1970-1971)
Lunokhod 2
(1973)
Pathfinder Sojourner traverse
is not visible at this scale

Clementine Designed Bands

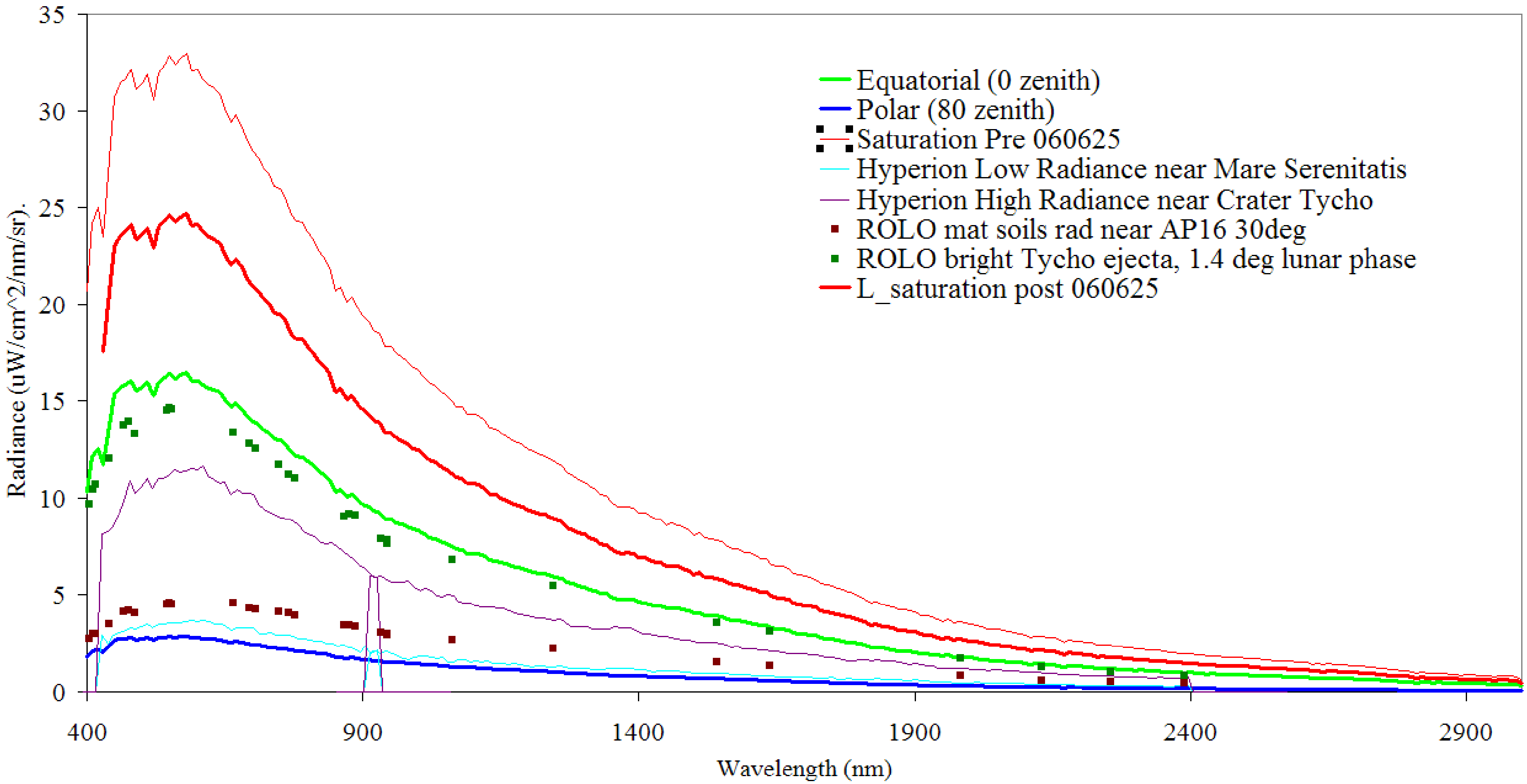


- Many of the spectral bands did not perform as expected

Traditional Multi-Spectral Filter Framing Approach

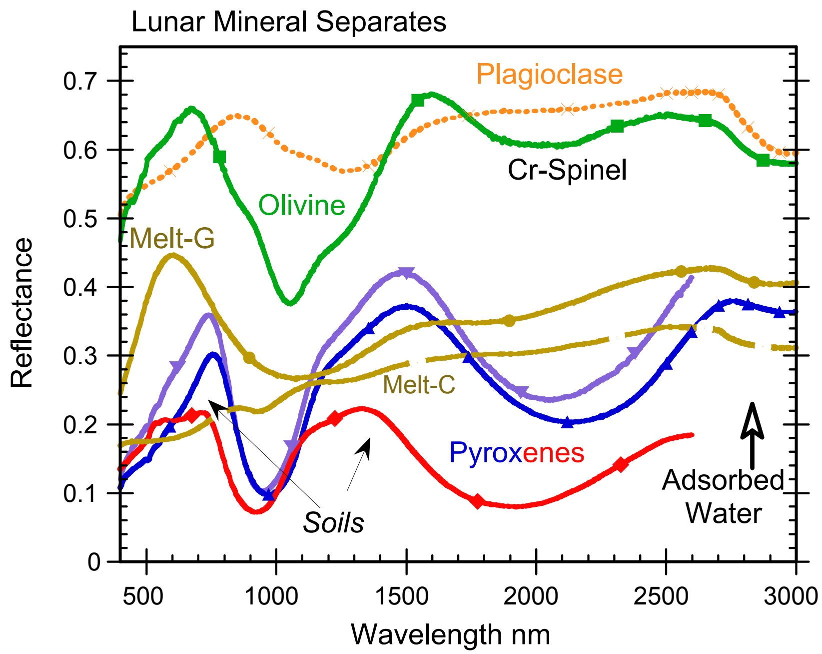


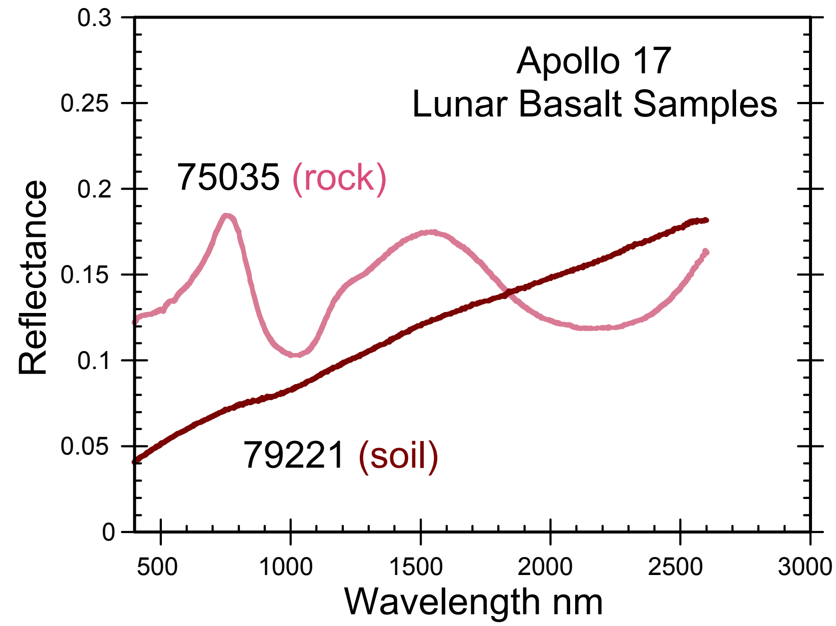
Existing Spectra of the Moon Radiance



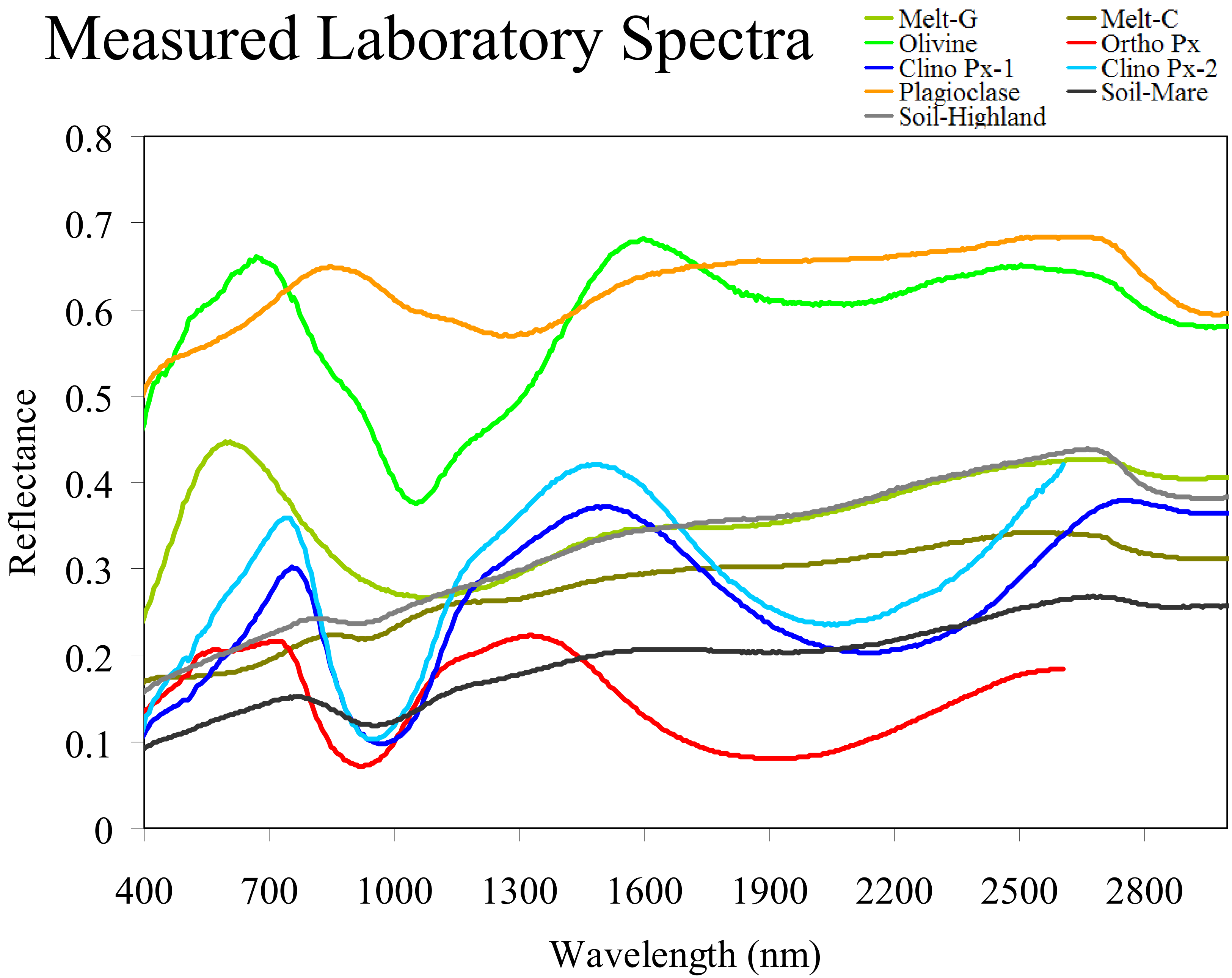
M^3 Approach and Plans

Spectral Signatures of the Moon





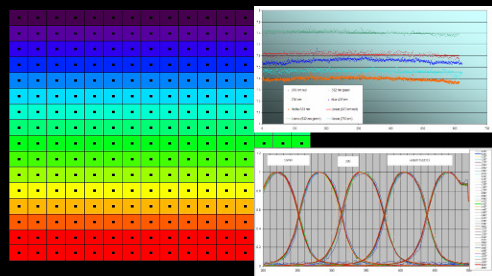
- Bidirectional Reflectance of returned lunar samples measured in the Reflectance Experiment Laboratory (RELAB) at Brown University illustrating some of the known spectral diversity on the Moon. [Left] Individual minerals separated from lunar rocks. [Right] An example of a lunar basalt and a mature soil from the same site. This spectral complexity requires a full spectrum to assess individual


Measured Laboratory Spectra
Melt-G
Melt-C
Olivine
Ortho Px
Clino Px-1
Clino Px-2
Plagioclase
Soil-Mare
Soil-Highland
Reflectance
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
700
1000
1300
1600
1900
2200
2500
2800
Wavelength (nm)

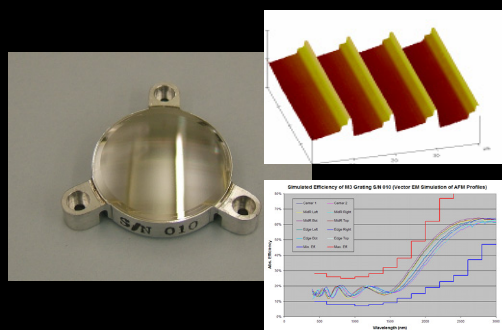
Moon Mineralogy Mapper (M3)

PI: Dr Carle Pieters, Brown University

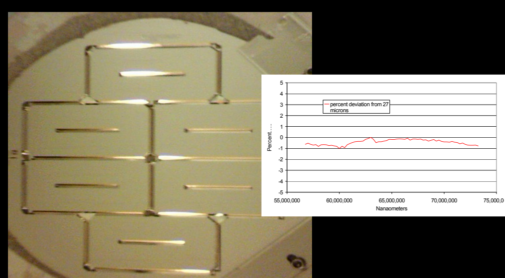
1) Mouroulis uniform & high SNR design



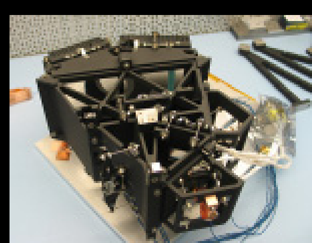
2) Electron beam grating with shaped groove on curved surface



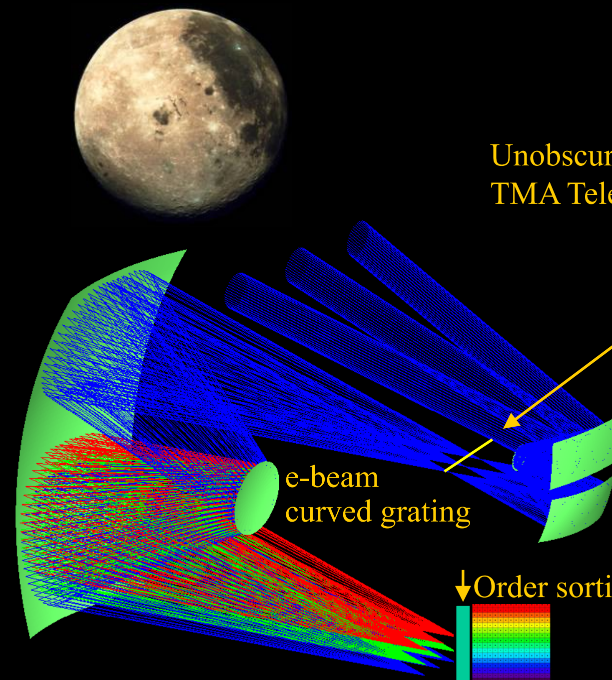
3) Electron beam slit. Parallel to 100 nm over 18,000,000 nm.



4) Spectrometer bench with submicron adjustment that remains stable

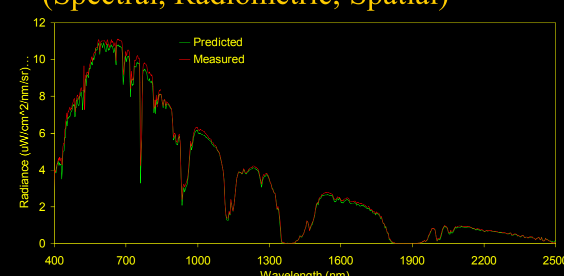


INSTRUMENT: JPL Uniform & High SNR Imaging Spectrometer

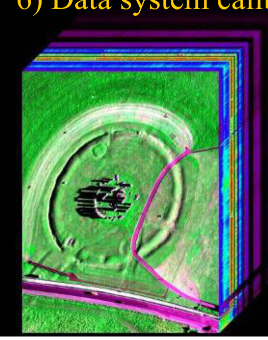


640 x-track elements
Single detector array
430 to 3000 nm

5) Alignment and Calibration (Spectral, Radiometric, Spatial)

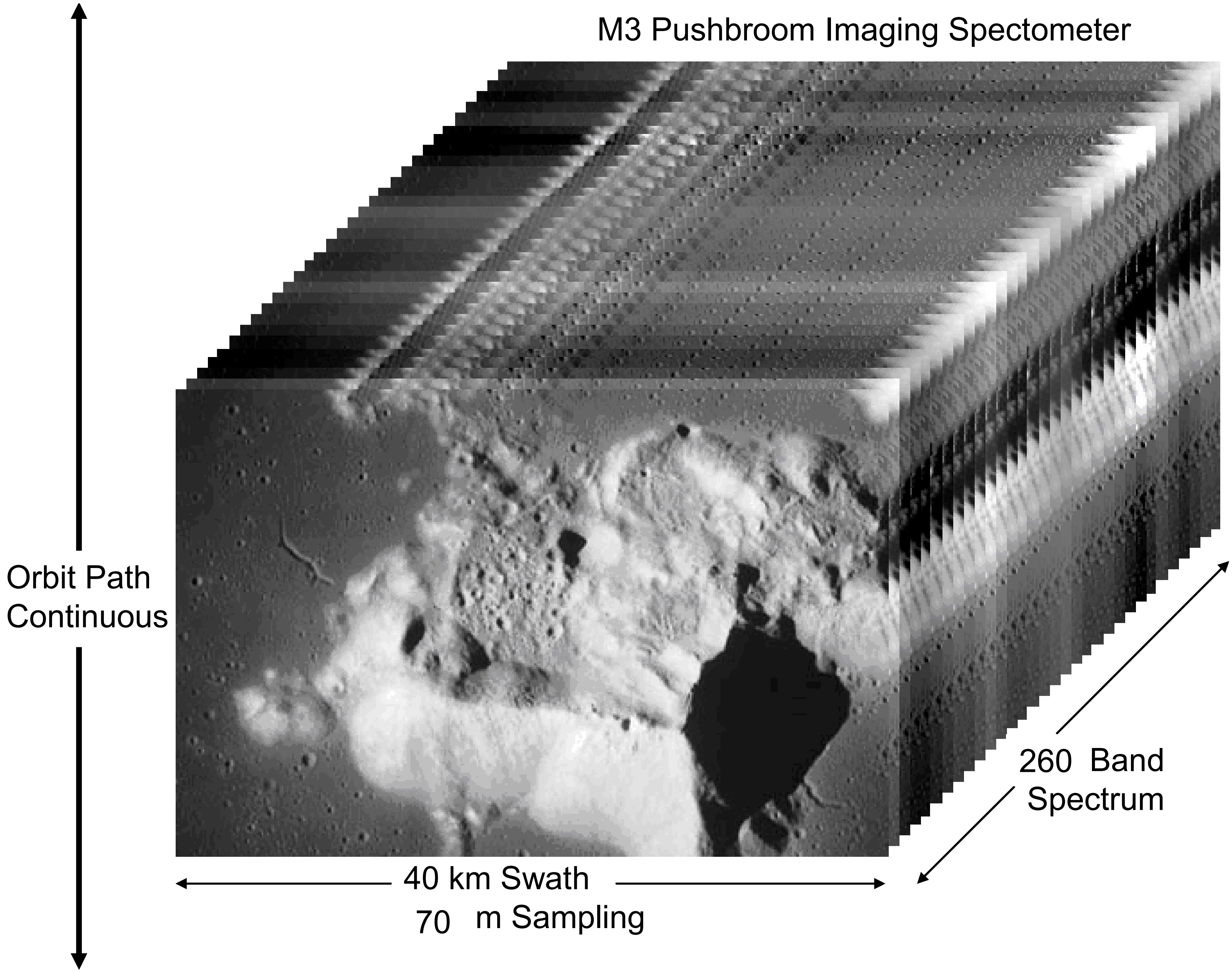


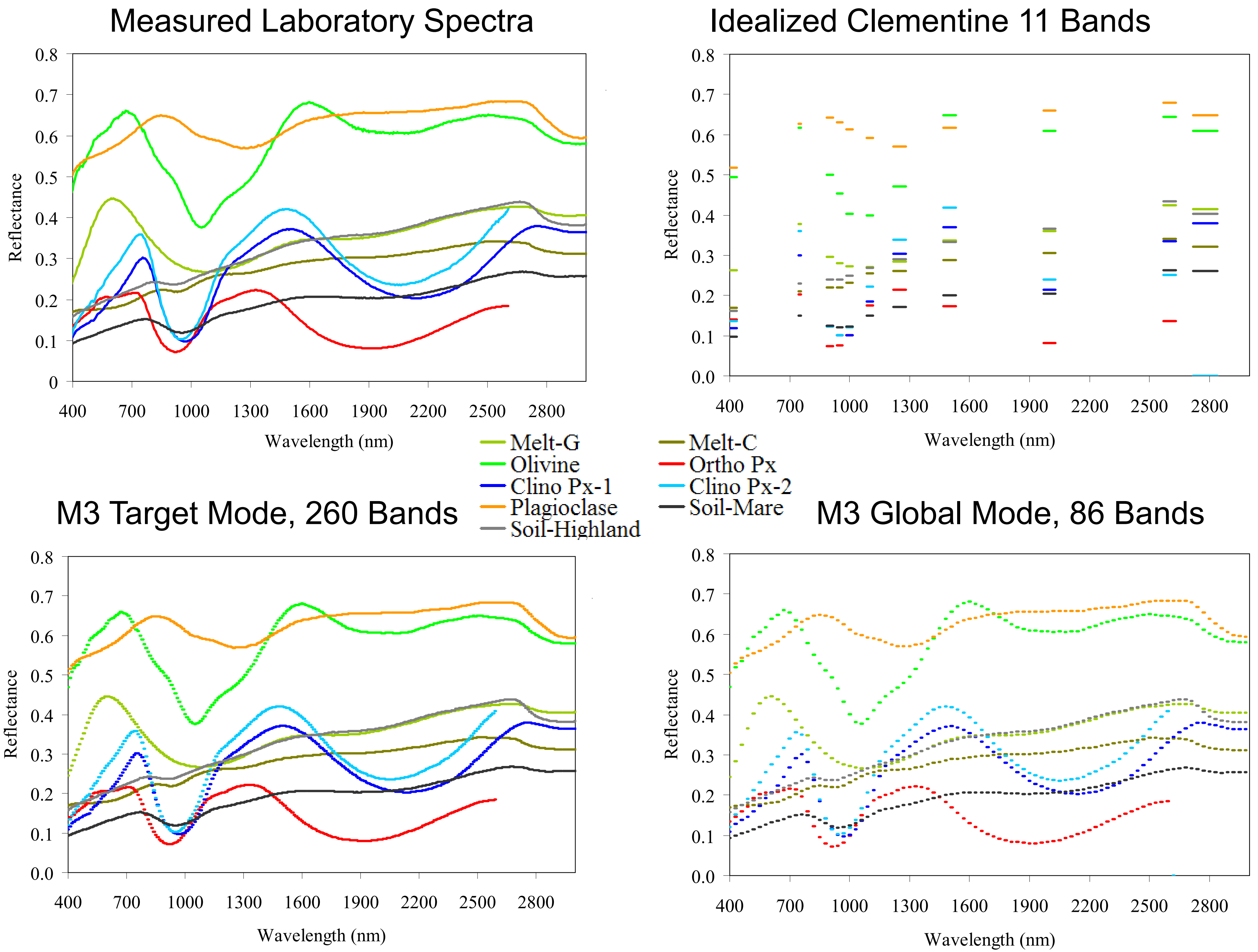
6) Data system calibration pipeline



M3 Science Measurement Requirement

Spectral	
Range	430 to 3000 nm in the solar reflected spectrum
Sampling	10 nm across spectral range
Response	FWHM 1.2 of sampling
Accuracy	Calibrated to 10% of sampling
Precision	Stable within 5% of sampling
Radiometric	
Range	0 to specified saturation radiance
Sampling	14 bits measured, 12 reported
Response	Linear to 1% (after calibration)
Stability	5% between calibrator views
Accuracy	10% absolute radiometric calibration
Precision (SNR)	>400 @ equatorial reference and >100 @ polar reference
Spatial	
Range	24 degree field-of-view
Sampling	0.7 milliradian cross and along track
Response	FWHM of IFOV @ 1.2 of sampling
Spectral-Spatial-Uniformity	
Spectral-Uniformity	< 10% variation of spectral position across the field of view
Spectral-IFOV	< 10% IFOVs variation over the spectral range

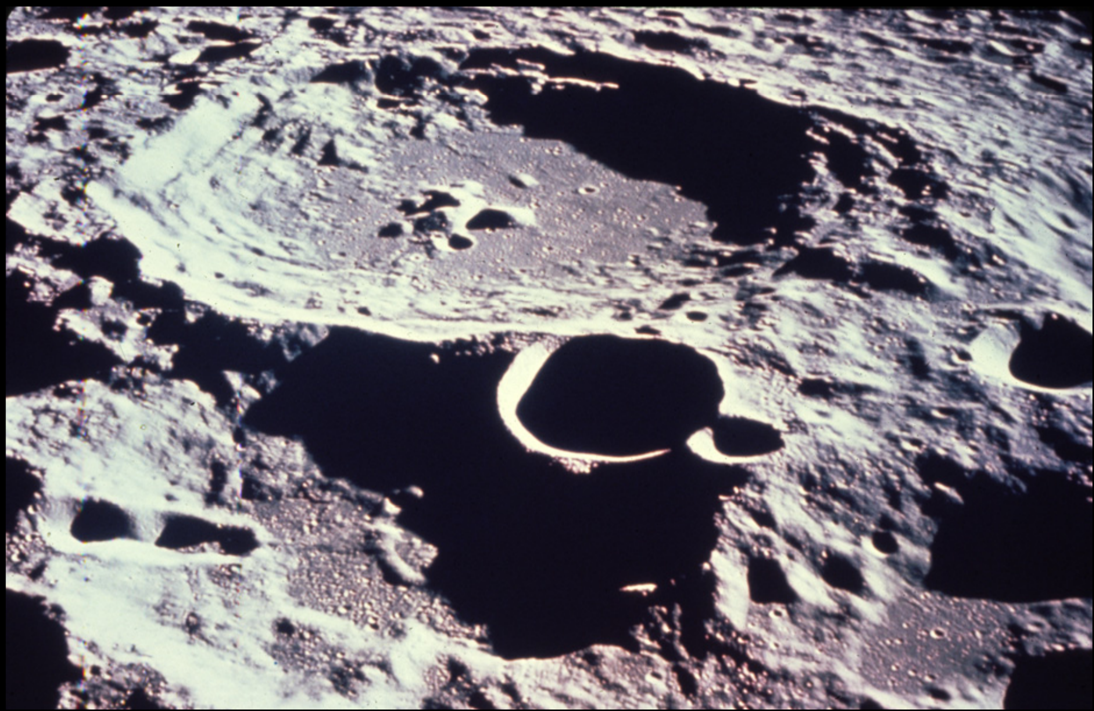

M3 Pushbroom Imaging Spectometer
Orbit Path
Continuous
260 Band
Spectrum
40 km Swath
70 m Sampling


Measured Laboratory Spectra
Idealized Clementine 11 Bands
M3 Target Mode, 260 Bands
M3 Global Mode, 86 Bands
Reflectance
Wavelength (nm)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
400
700
1000
1300
1600
1900
2200
2500
2800
Melt-G
Olivine
Clino Px-1
Plagioclase
Soil-Highland
Melt-C
Ortho Px
Clino Px-2
Soil-Mare

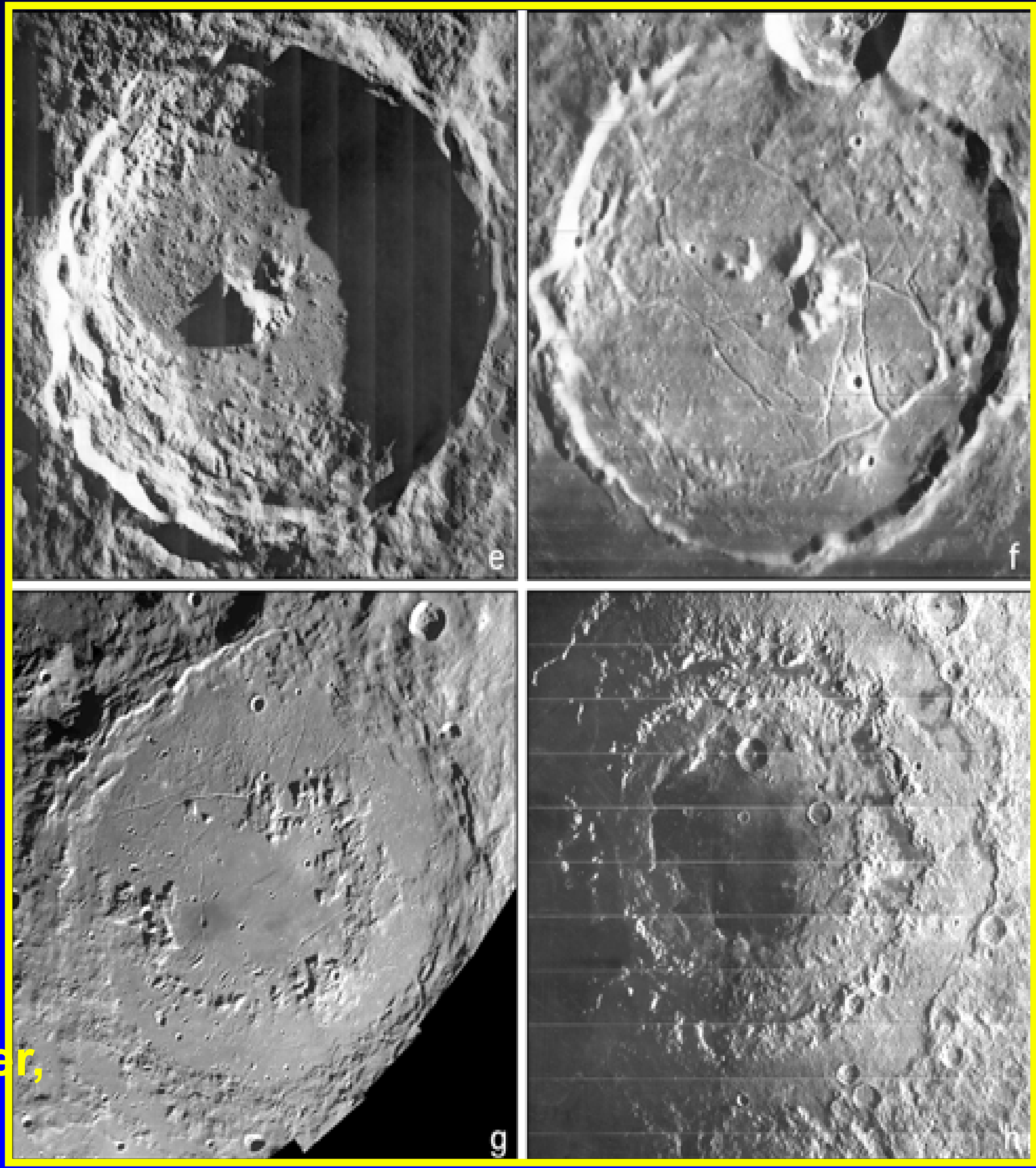
Impact Cratering

Nature of the Process

- Depth of Excavation.
- Role of oblique impact.
- Modification stage.
- Production of impact melt.
- Ejecta emplacement dynamics.
- Role of volatile emplacement and fate



Lunar Craters and Basins



Tycho,
85 km

Gassendi,
110 km

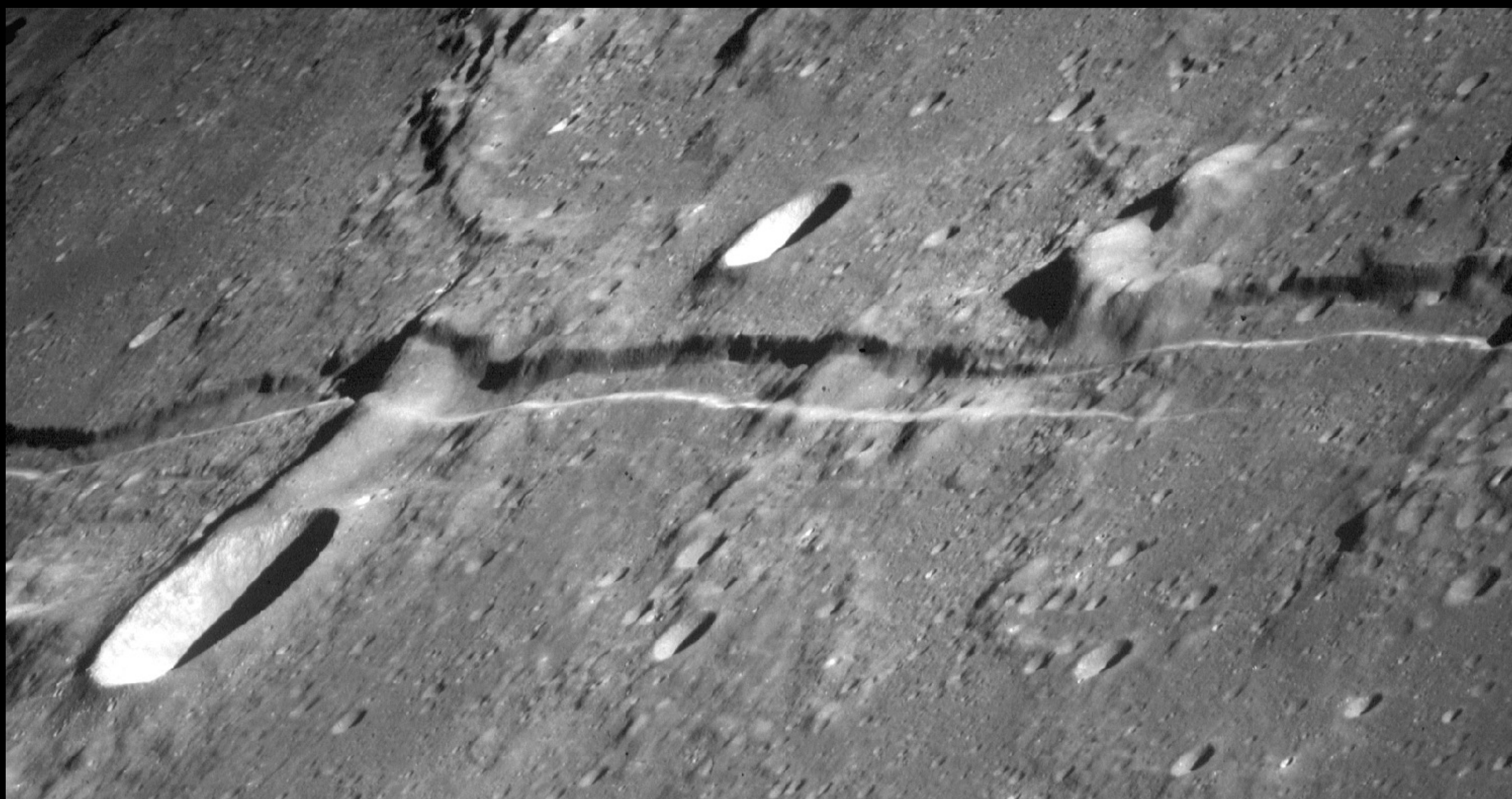
Schroedinger,
320 km

Orientale,
930 km

Tectonic Activity

Graben

Distinguishing magmatic and tectonic graben.



Tectonic Activity

Wrinkle Ridges

Detailed composition and Understanding

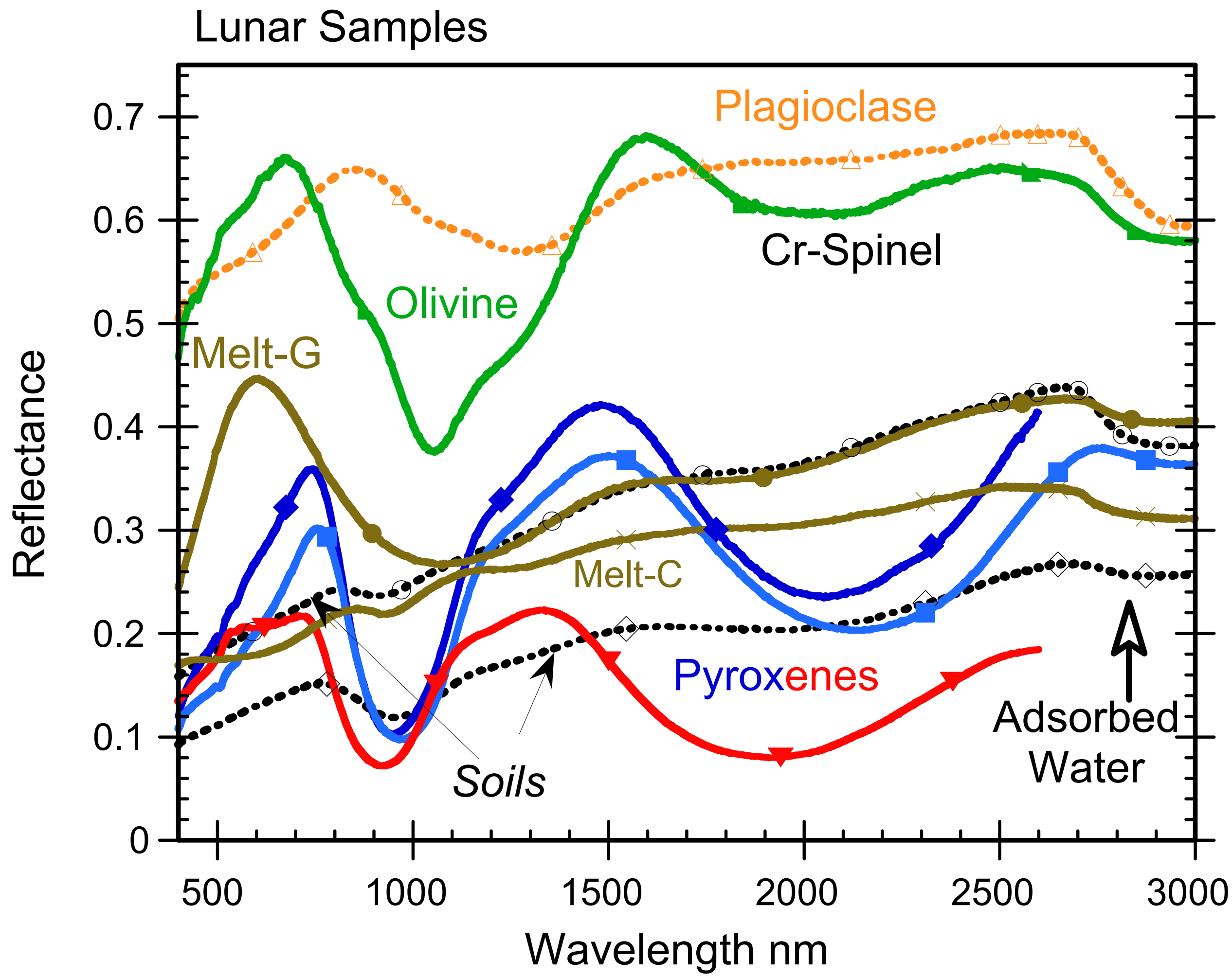
Sinuous Rilles

M^3 Science Goals via Imaging Spectroscopy

- Primary Science Goal: Characterize and map the lunar surface composition in the context of its geologic evolution. This translates into several science sub-topics to be addressed.

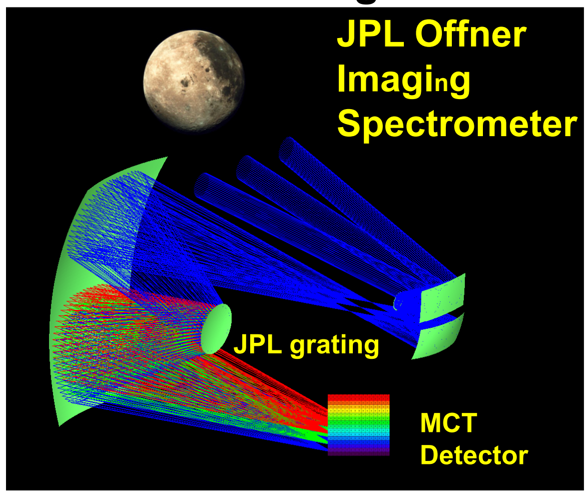
- Primary Exploration Goal: Assess and map the Moon mineral resources at high spatial resolution to support planning for future, targeted missions.

M3 Science is based in Spectroscopic Measurement of the Lunar Surface.



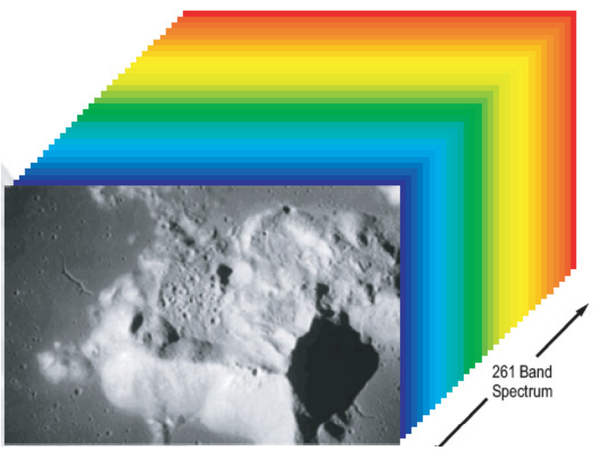
M3 Measurements

Uniform Full Range Instrument



Spectroscopic Analysis to Answer the Science Questions and Meet the Mission Requirements

Calibrated Spectral Image Cubes



Reflectance Spectra